A DEDICATED STORAGE RING FOR INFRARED SYNCHROTRON RADIATION AT THE ALS

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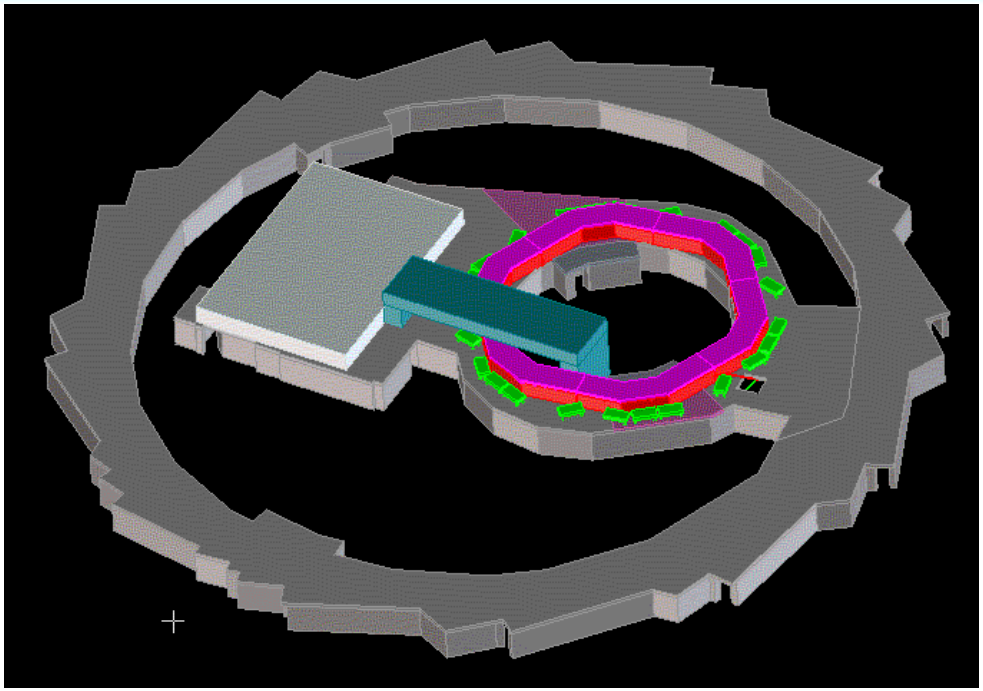
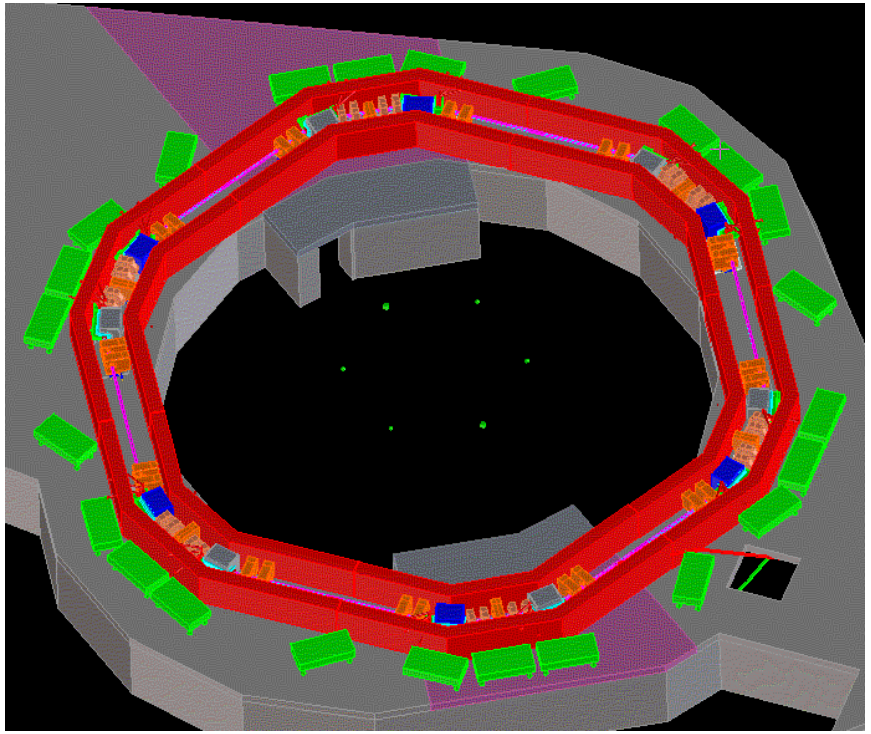
Introduction

- IR beamlines operate parasitically, comparable to the original SR users on HEP machines.
- Typical bend magnet sources are not optimized for far-IR light. The large opening angle usually does not clear the beam pipe which has been designed for x-rays. The heat load from x-rays creates additional problems for IR light collection.
- Typical 3rd generation rings have much lower transverse emittance than necessary for IR light.
- IR beamlines requires much less floor space due to right angle deflection than x-ray beamlines.
- The production of stable coherent SR in the far-infrared may enable new science.
- Why not build a storage ring optimized for IR SR?

Booster shielding solution



A 300-700 MeV storage ring sited on top the ALS booster shielding



-"Free" full energy (700 MeV) injector-ALS main ring fills at 8 hour intervals.

-Adequate floor space for IR beamline experiments.

-Stable surface supporting ring and beamline.

IR Ring History

- 1994: Compact SXLS source at NSLS/BNL proposed to be used as coherent far-infrared source. Proposal not pursued due to lack of experience in superconducting RF.
- May 1999: first proposal for IR ring inside booster tunnel.
- FY 2000: LDRD awarded for further developing far-IR sources at the ALS.
- Oct. 2000: dedicated ring concept presented to user's at IR workshop.
- Oct. 2000: set goal of developing ring with guaranteed conventional mode and possible coherent mode.
- Feb. 2001: First observation of bursts of coherent far-infrared SR from the ALS.
- Apr. 2001: concept presented at ALS planning meeting.

IR Ring History (cont.)

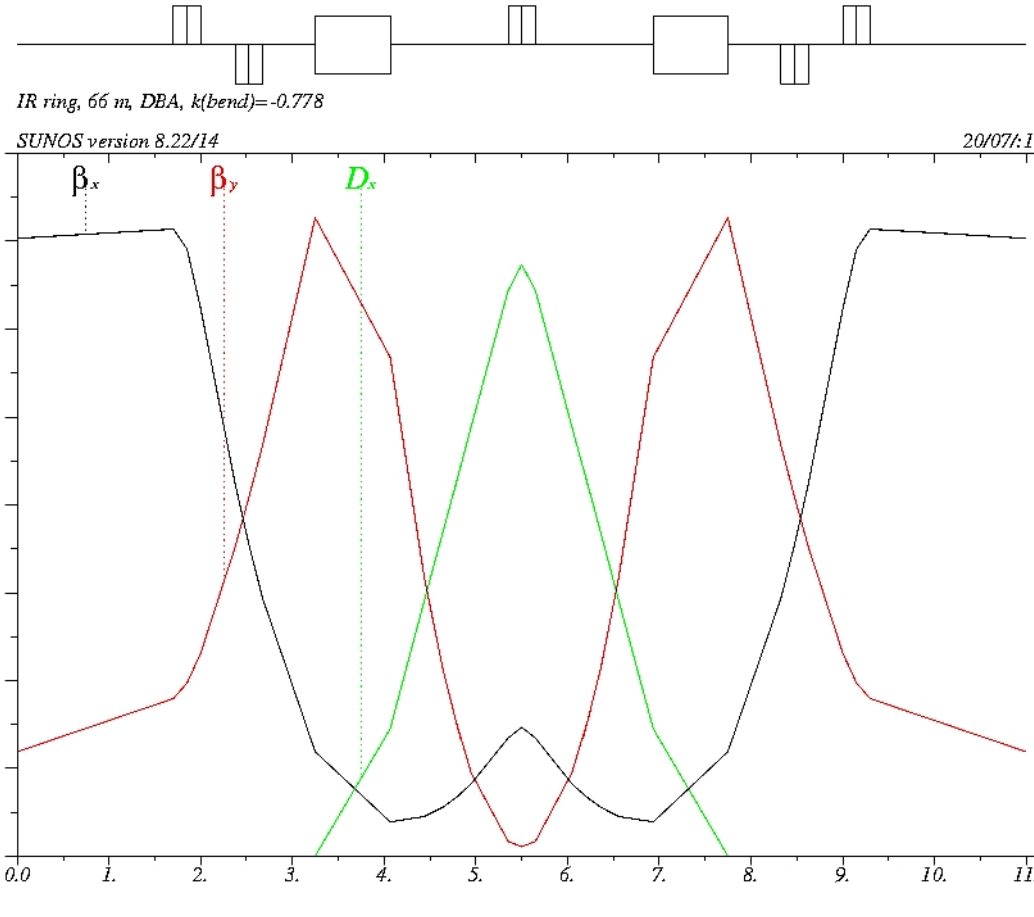
- FY 2001: strategic LDRD awarded for developing ring concept.
- Oct. 2001: conceptual ring design presented at ALS Infrared Spectromicroscopy and Future Infrared Sources Workshop,
- Nov. 2001: First evidence of stable CSR observed in Bessy-II.
- Jan. 2002: Evidence of stable CSR observed at ALS.
- Feb. 2002: Project focus shifted to delivering coherent mode ab initio. Plan to still provide conventional mode.

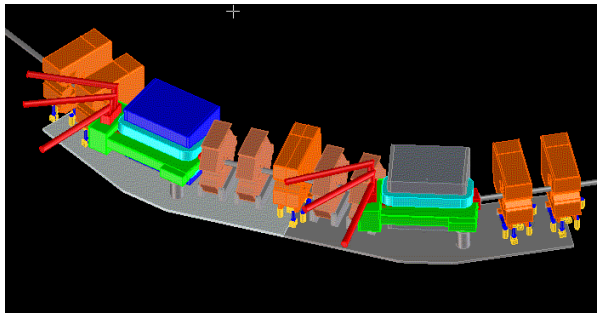
Project Goals

- Produce a coherent source of far-IR SR that will dramatically enhance scientific capabilities in this wavelength range.
- Provide the highest quality IR SR source in the world.
- Do the above for about the cost of an expensive ALS beamline (10-20 M$).

Conventional Mode

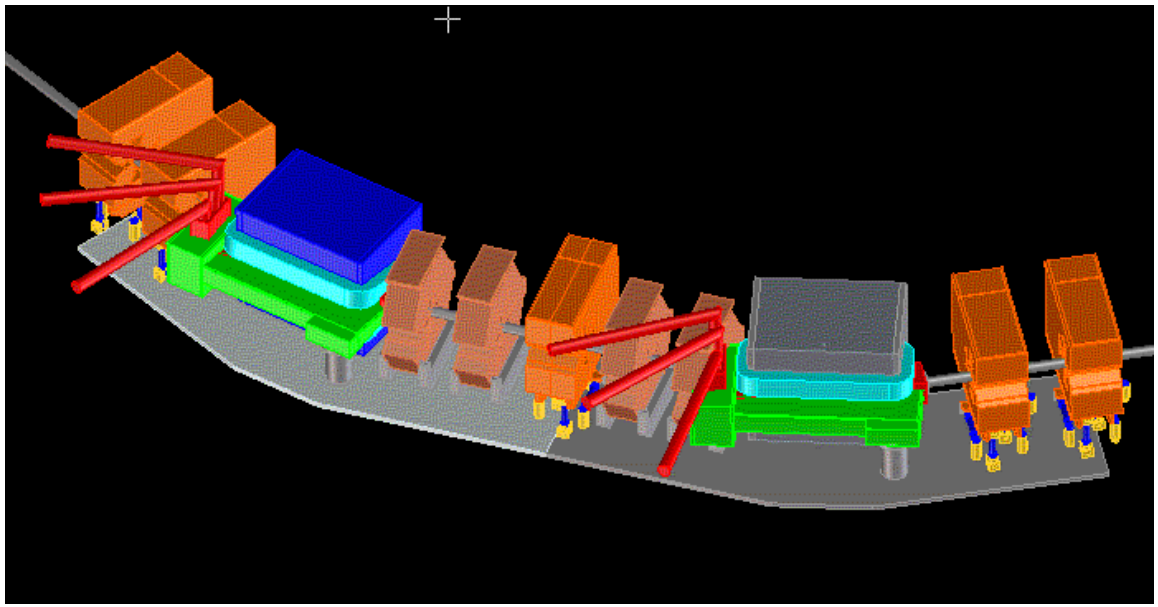
Double Bend Achromat
(with Gradient in the Dipoles)





Energy [MeV]	700
Current [A]	1
Emittance [nm]	50
Momentum Compaction	$6\ 10^{-3}$
Lifetime [hr]	4 - 5

IR Ring Period Layout

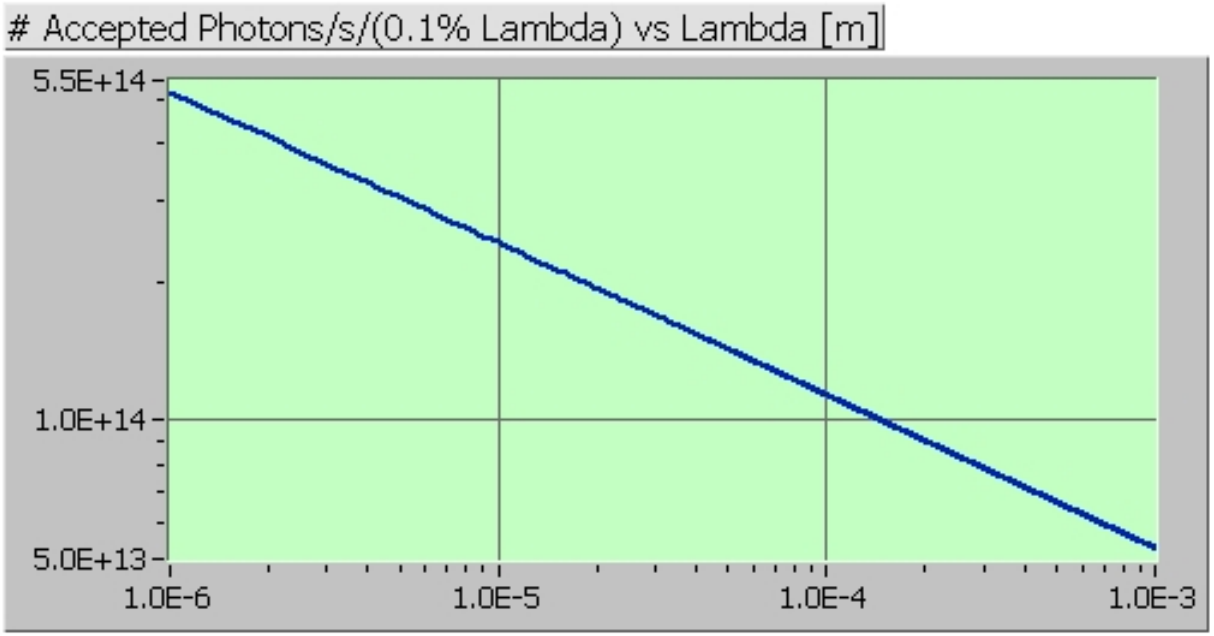


Ring Length [m]	66
Lattice Periodicity	6
Dipoles/Period	2
Dipole Radius [m]	1.56
Quads/Period	5
Sextupoles/Period	4 (6)
Straight Section Length [m]	3.4

3 Beam Lines/Dipole

36 Total IR Beam Lines

Single Beam Line Photon Flux (Conventional Mode)



I = 1 A

Single Beam Line Acceptance: 100 x 140 mrad²

ε_C ~ 490 eV

ρ_{ALS} = 4.0 m
ρ_{IRR} = 1.6 m

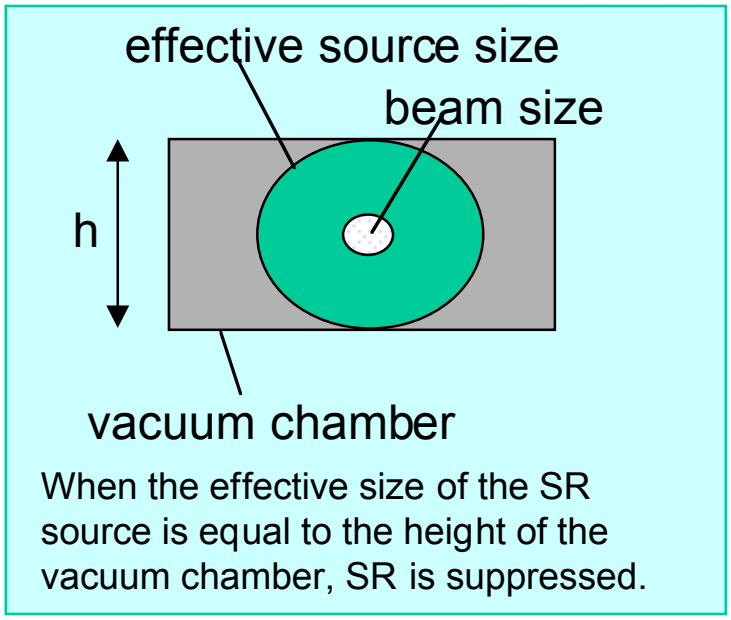
~ Same Depth of Field Of ALS 1.4 (40x10 mrad²)

λ	$Flux_{IRR}/Flux_{ALS}$
1 μm	~ 5
1 mm	~ 50

Vacuum Chamber as a High Pass Filter

The SR spectrum does not extend to DC. The vacuum chamber acts as a high pass filter in two ways:

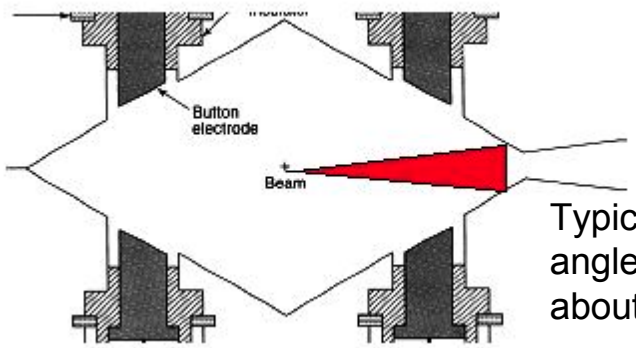
- shielding
- reduced vertical aperture in antechamber design



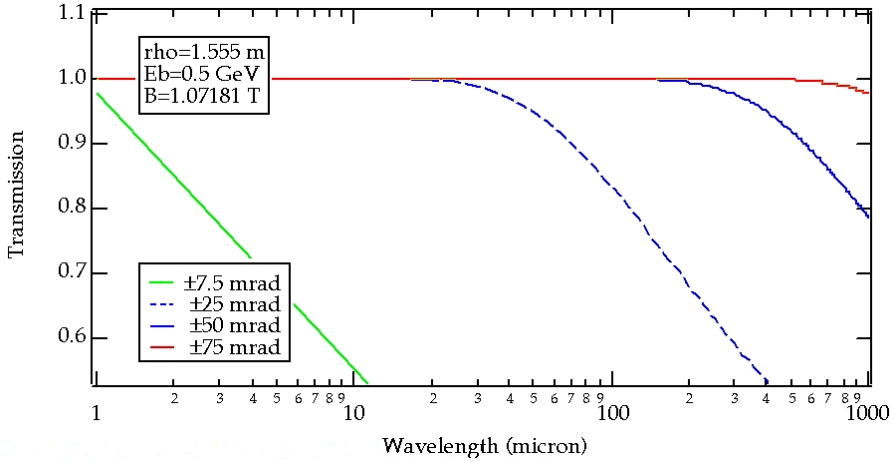
When the effective size of the SR source is equal to the height of the vacuum chamber, SR is suppressed.

$$\theta_{rad} = \left(\frac{\lambda}{\rho}\right)^{1/3}$$ opening angle

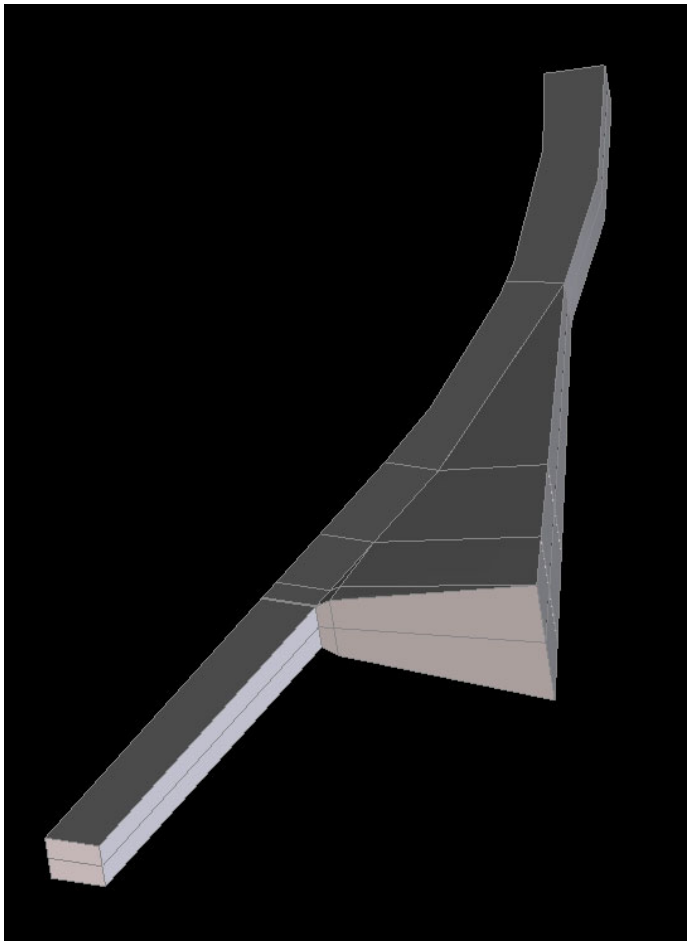
$$\sigma_{source} = \frac{\lambda}{\theta_{rad}} = \lambda^{2/3}\rho^{1/3}$$ diffraction limited source size

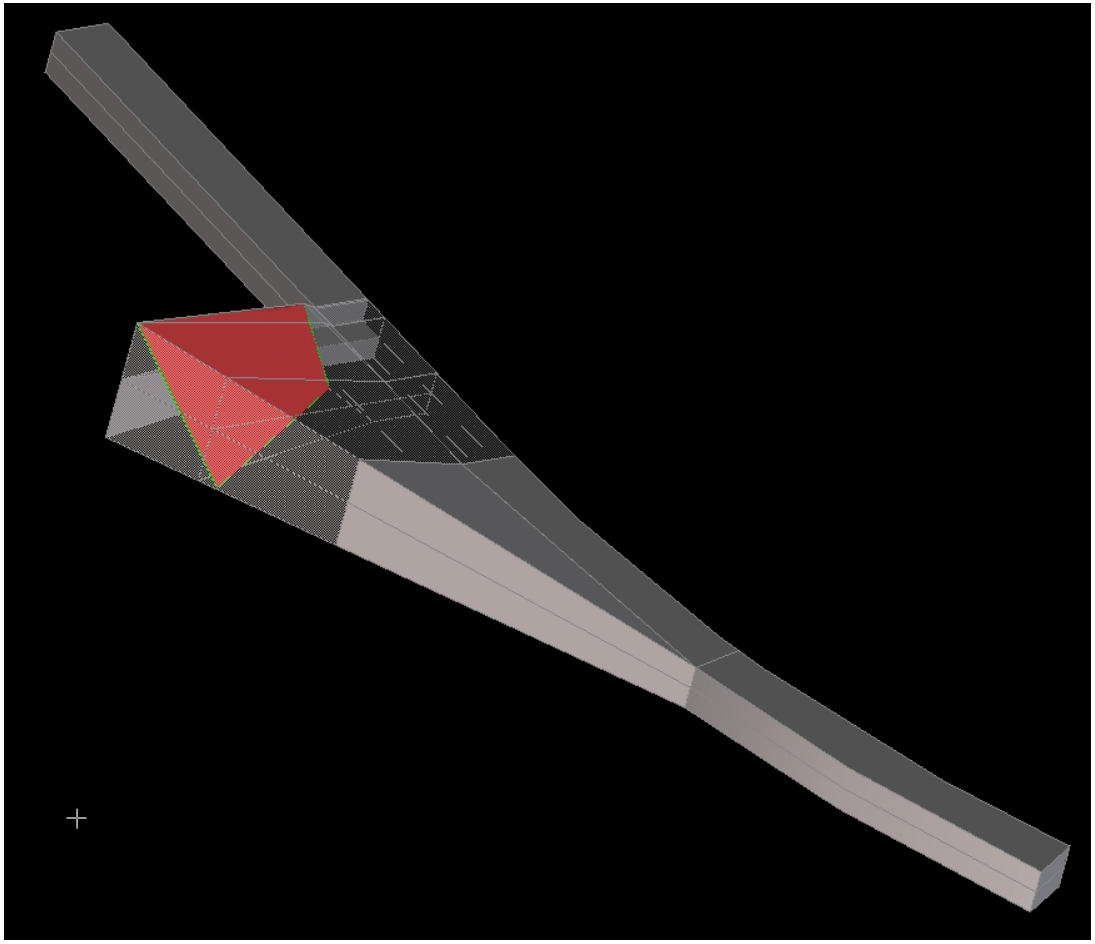


Typical opening angles for far-IR about 6 degrees.



Dipole Vacuum Chamber





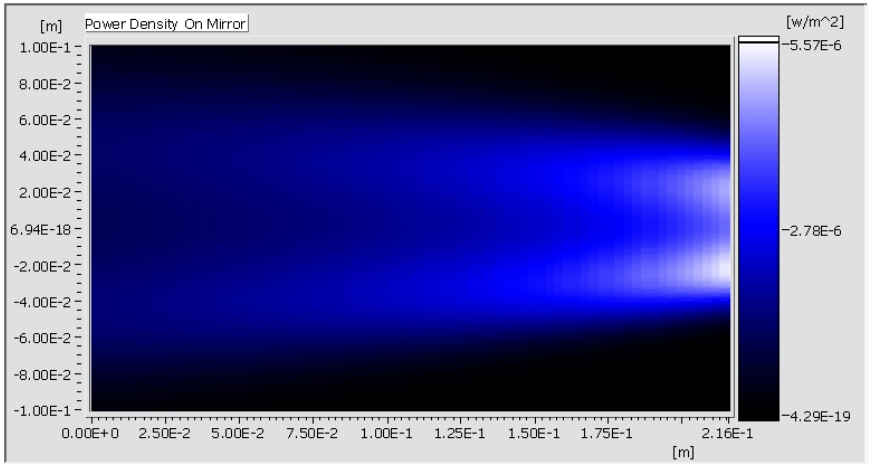
'Horn' Shape Compatible with Gradient Dipoles

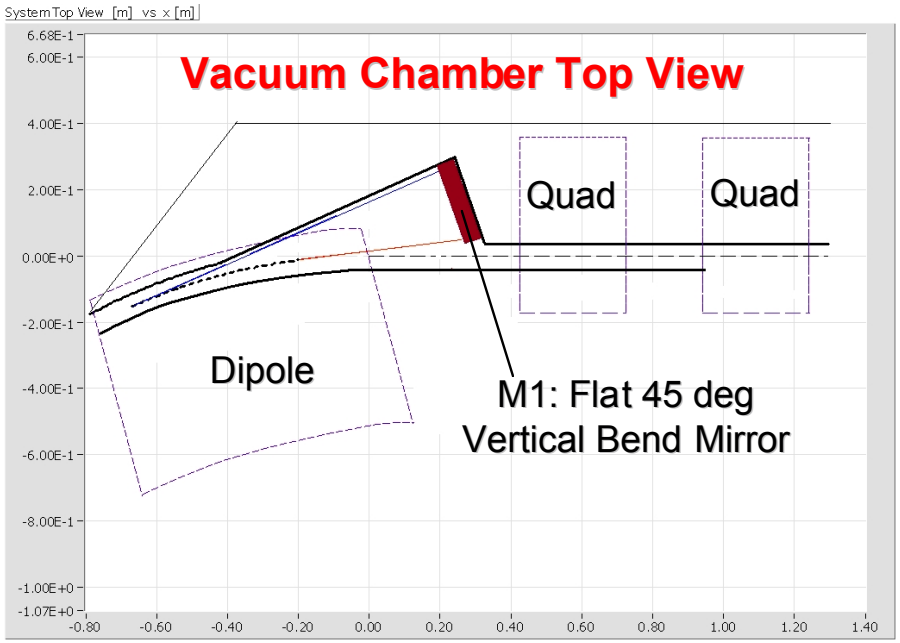
Large Acceptance Vacuum Chamber

M1 Mirror Vertical Acceptance: 140 mrad

95% of the radiation at λ = 1 mm

Photon Distribution on M1 at λ = 1 mm

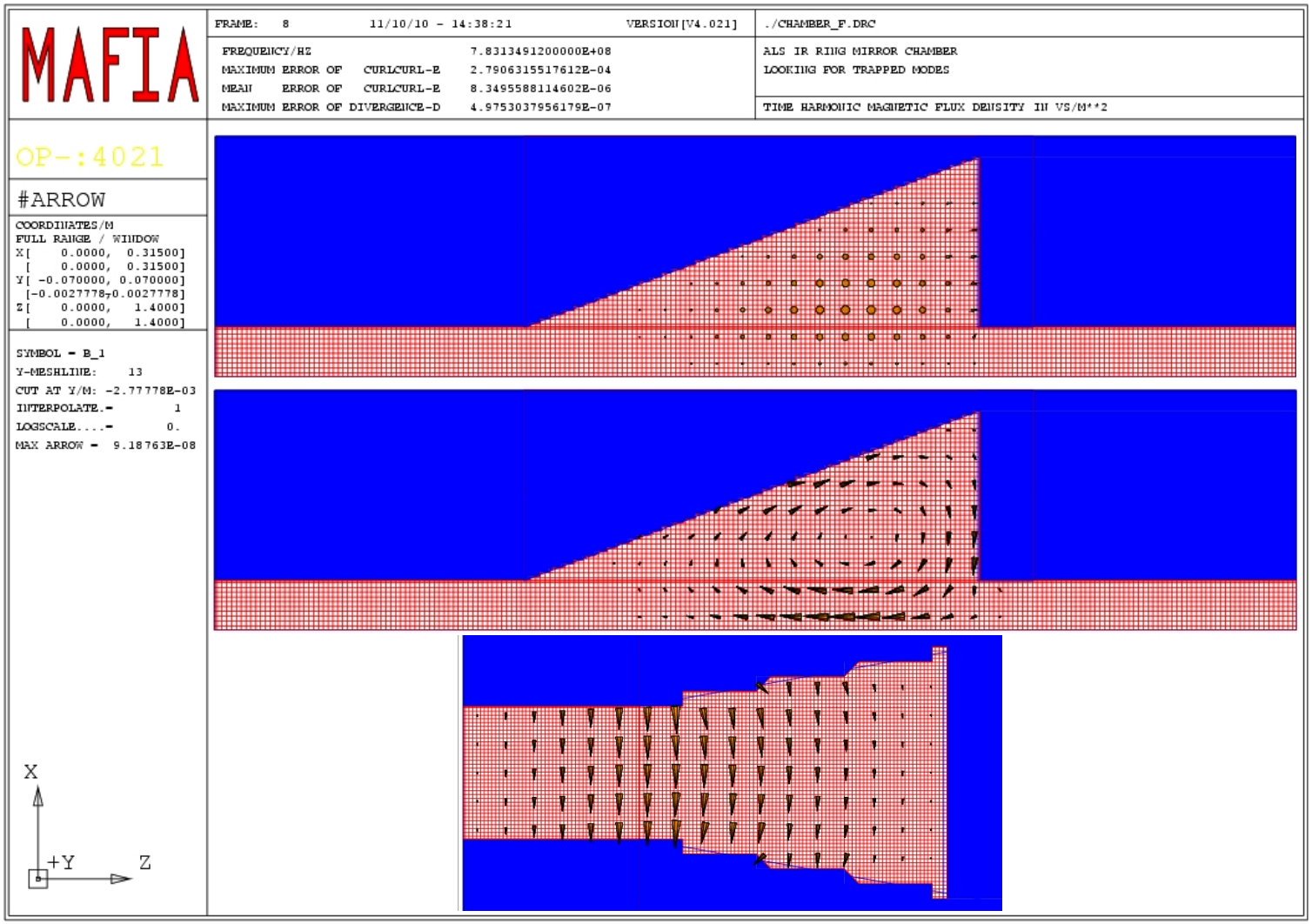




M1 Mirror Total Horizontal Acceptance: 300 mrad

60% of the electron beam trajectory in the Dipole

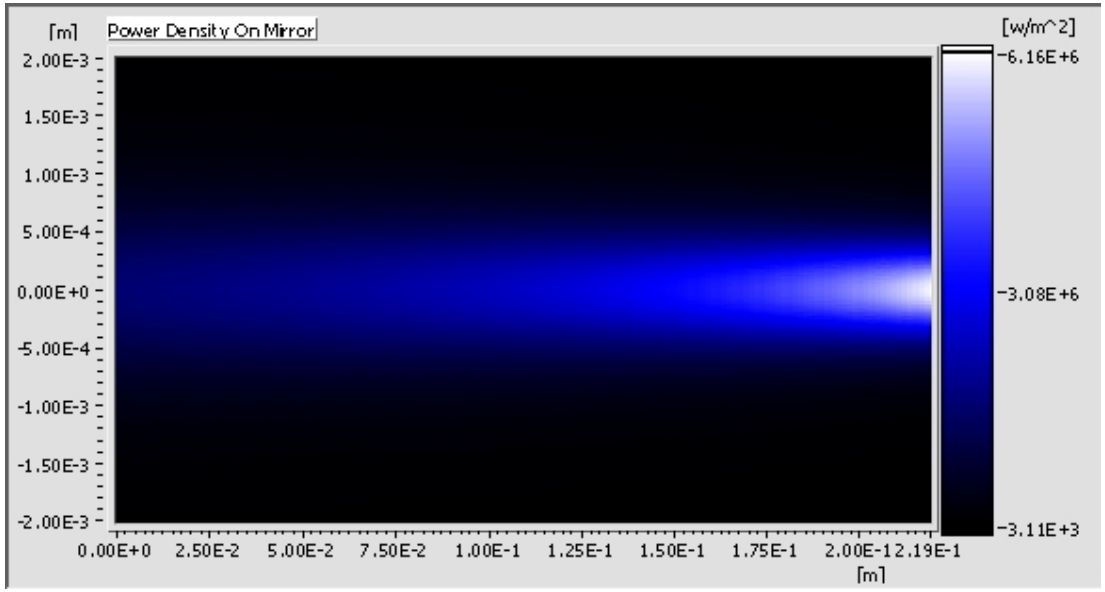
Beam Impedance Issues



Photon Beam Stability

- Booster Shielding Vibration Measurements
  - Same or better than ALS Floor!
- Very Short Distance Source-Experiment
  - Reduced Sensitivity to Noise
- Large Vertical Acceptance & No finger or Slot on Mirror M1
  - Amplitude Modulation Reduction
- Studies on BL 1.4 Noise Dependence
  - ALS already the most quiet SR source
  - existing noise ~5 times that of blackbody source

M1 Mirror Thermal Analysis



No Finger or Slot

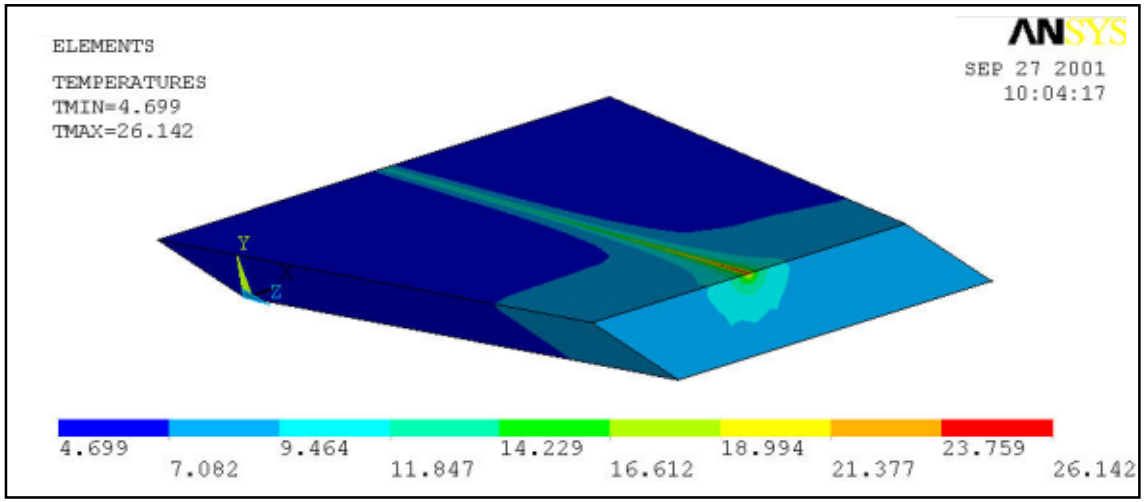
For X-Ray Removal

Water Cooled Glidcop

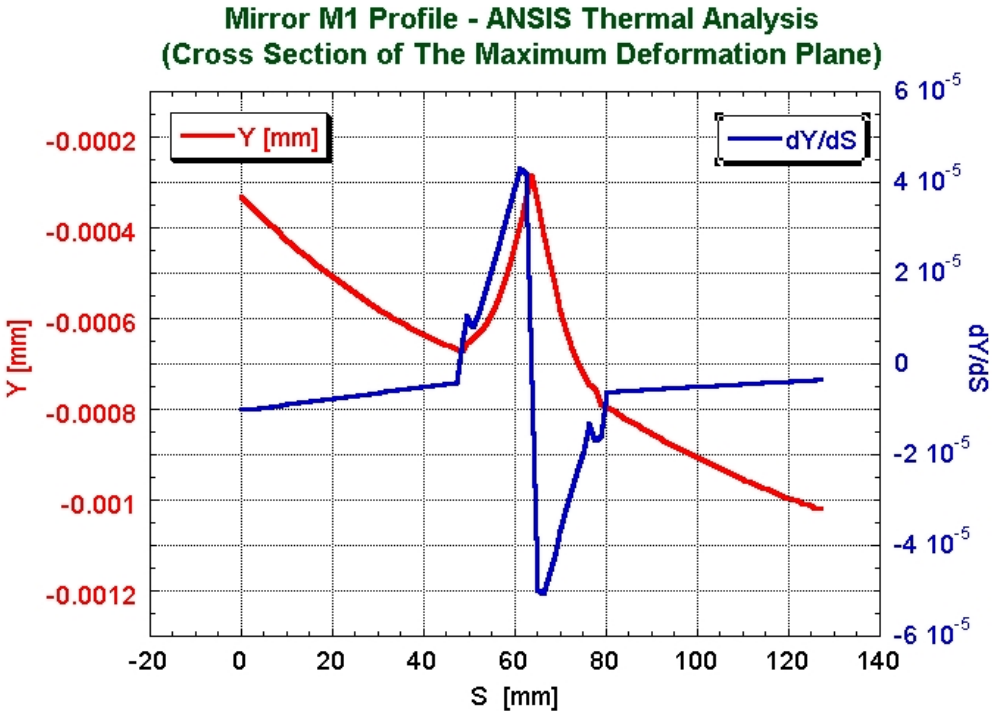
X- Ray Heat Load
~ 700 W

6 W/mm²

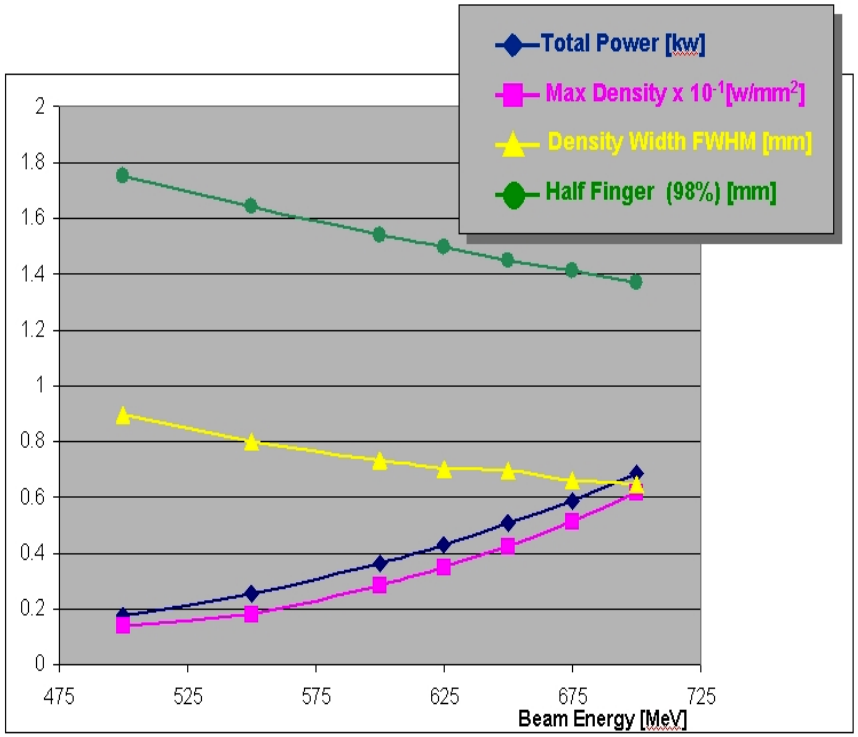
0.6 mm FWHM



M1 Mirror Optical Quality



Optical Quality Under Analysis



Possible Knob: Electron Beam Energy

Coherent Synchrotron Radiation

When the electron bunch is comparable to the SR wavelength, the individual electrons radiate coherently and the intensity scales with N^2.

$$P(\omega) = p(\omega)\left[N + N(N-1)g(\sigma_l)\right]$$

INCOHERENT

COHERENT

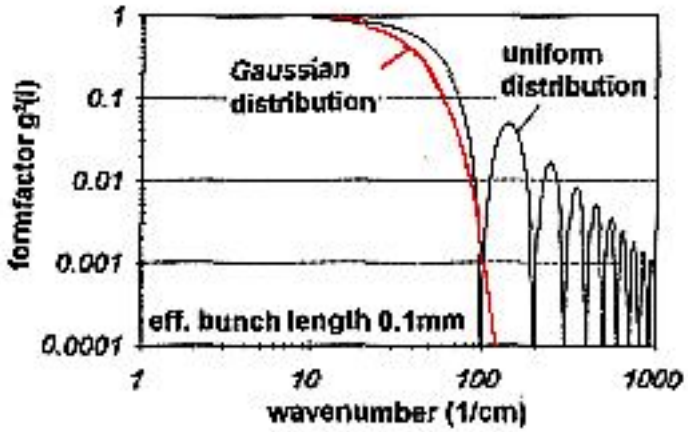


FIGURE 3. Form factor for a Gaussian and rectangular particle distribut

Typical storage rings have bunch lengths greater than 5 mm, so most SR is incoherent.

For a gaussian bunch distribution, coherent radiation will occur (in free space) when:

$$\pi\sigma < \lambda$$

Since: $N > 10^6$

the potential gain is large.

A Possible Coherent FIR Source

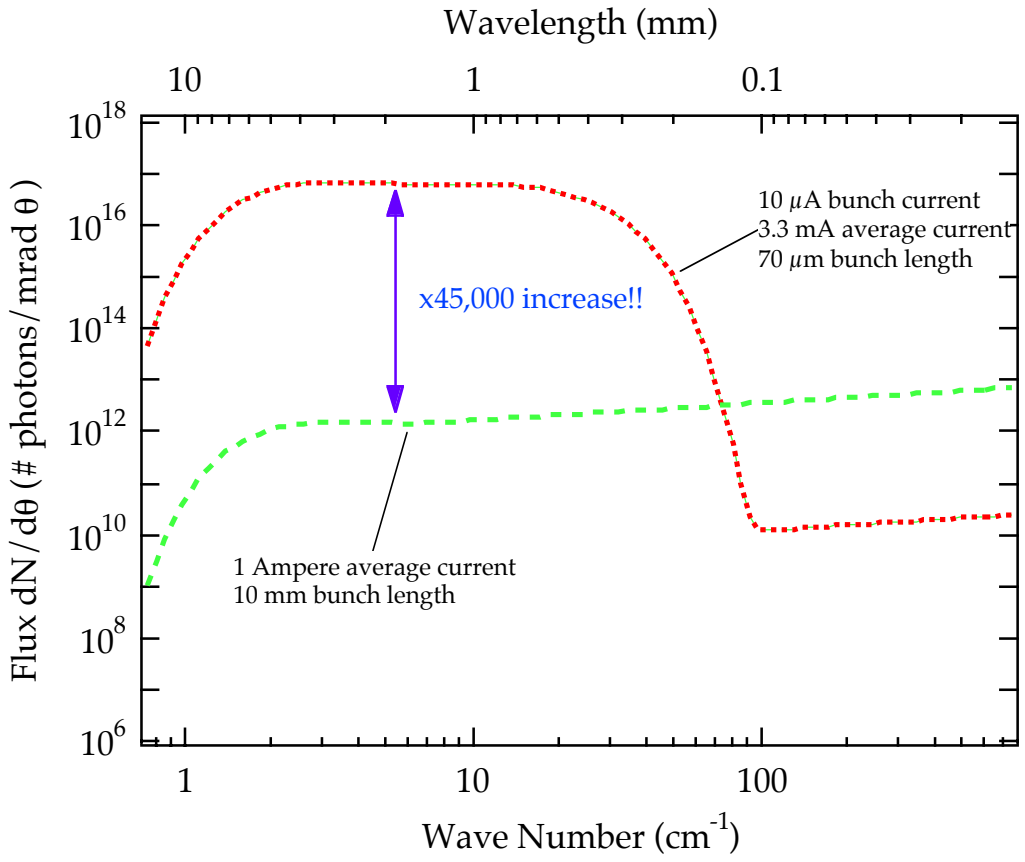
Coherent SR can occur in the wavelength range

$$\pi\sigma < \lambda < 2h\left(\frac{h}{\rho}\right)^{1/}$$

Bunch Shortening Knobs:

$$\sigma_l \alpha \left(\frac{\alpha E^3}{f_{rf} V_{rf}}\right)^{1/2}$$

With Reasonable Numbers:
Large enhancement in the 0.1-10 mm range is theoretically possible!



(Originally Inspired by Jim Murphy)

IR Ring in the Coherent Mode

Energy [MeV]	300
RF (Super Conductive)	1.5 [GHz]
RF Voltage	~ 2 [MV]
Mom. Compaction	~ 3 10^{-4}
rms Bunch Length	200 [fs]
Current/Bunch	10 [μA] (N ~1.4 10^{7})
Max. Number of Bunches	330

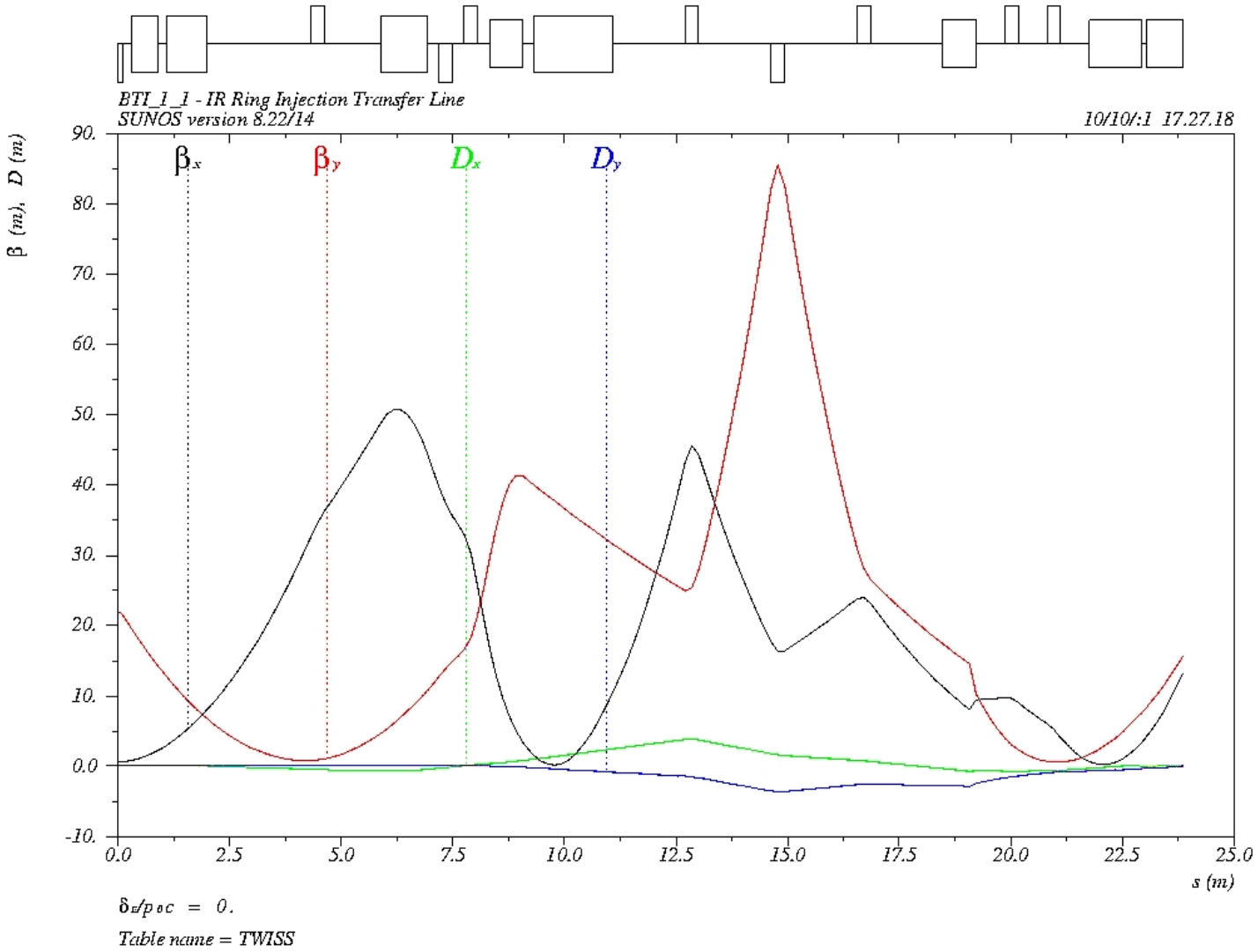
Small current/bunch for avoiding microwave instabilities (bunch lengthening)

Very small current: no cavity beam loading

~ 50,000 times higher FIR flux (0.1 – 10 mm) than in the conventional mode with 1 A current

First evidence for coherent mode observed at Bessy-II!

BTI: Booster to IR Ring Transfer Line



Cost Estimate

Item	Cost (M$)	Contingency (M$)
•Magnets/supports	2.9	1.0
•Ring vacuum system	1.0	0.5
•Power supplies	0.6	0.2
•RF system	1.2	0.4
•Injection	1.5	0.5
•Instrumentation/Controls	0.9	0.3
•Installation/Facilities	1.6	0.7
•Project management	0.5	0.1
subtotal	10.2	3.7
18 front ends (half ring)	1.2	0.4
subtotal	11.4	4.1
Overhead @ 10%	1.1	
escalation (2 yrs @ 6%)	1.4	0.5
TOTAL	13.9	4.6

Summary

- Project priority refocussed to producing stable source of coherent radiation and establishing strong scientific motivation for such as source.
- Experimental evidence for CSR appears very promising. Collaboration formed with Bessy-II to further investigate.
- Preliminary studies indicate no showstoppers for 700 MeV ring on the booster roof. Solutions proposed for all ring technical issues in the conventional mode.